Statistical Model Checking for Traffic Models

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December 9, 2021 - SBMF 2021 - 24th Brazilian Symposium on Formal Methods

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Background and Motivation

Tools

Integration of MultiVeStA and SUMO

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Future Directions

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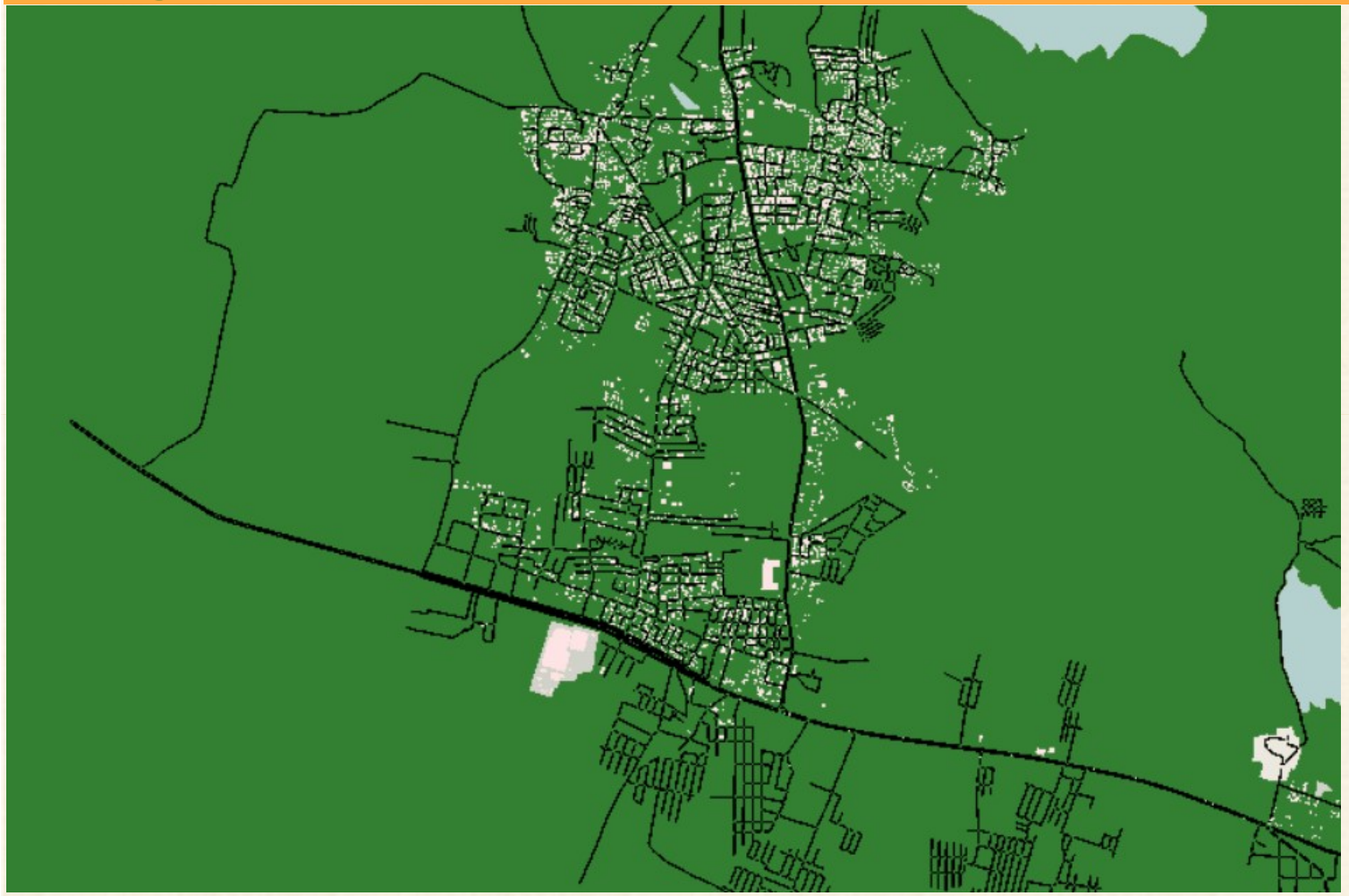
Background and Motivation



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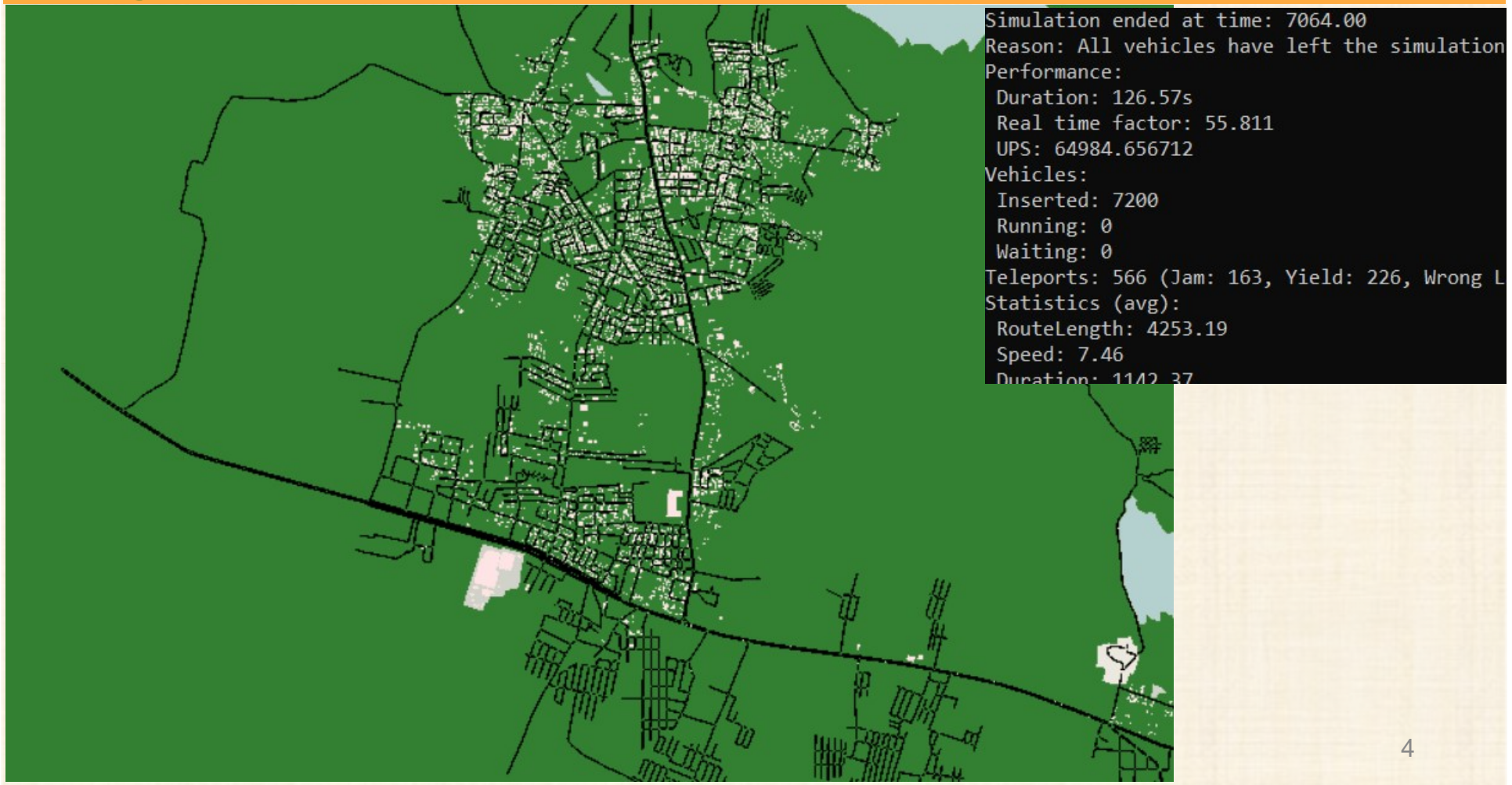

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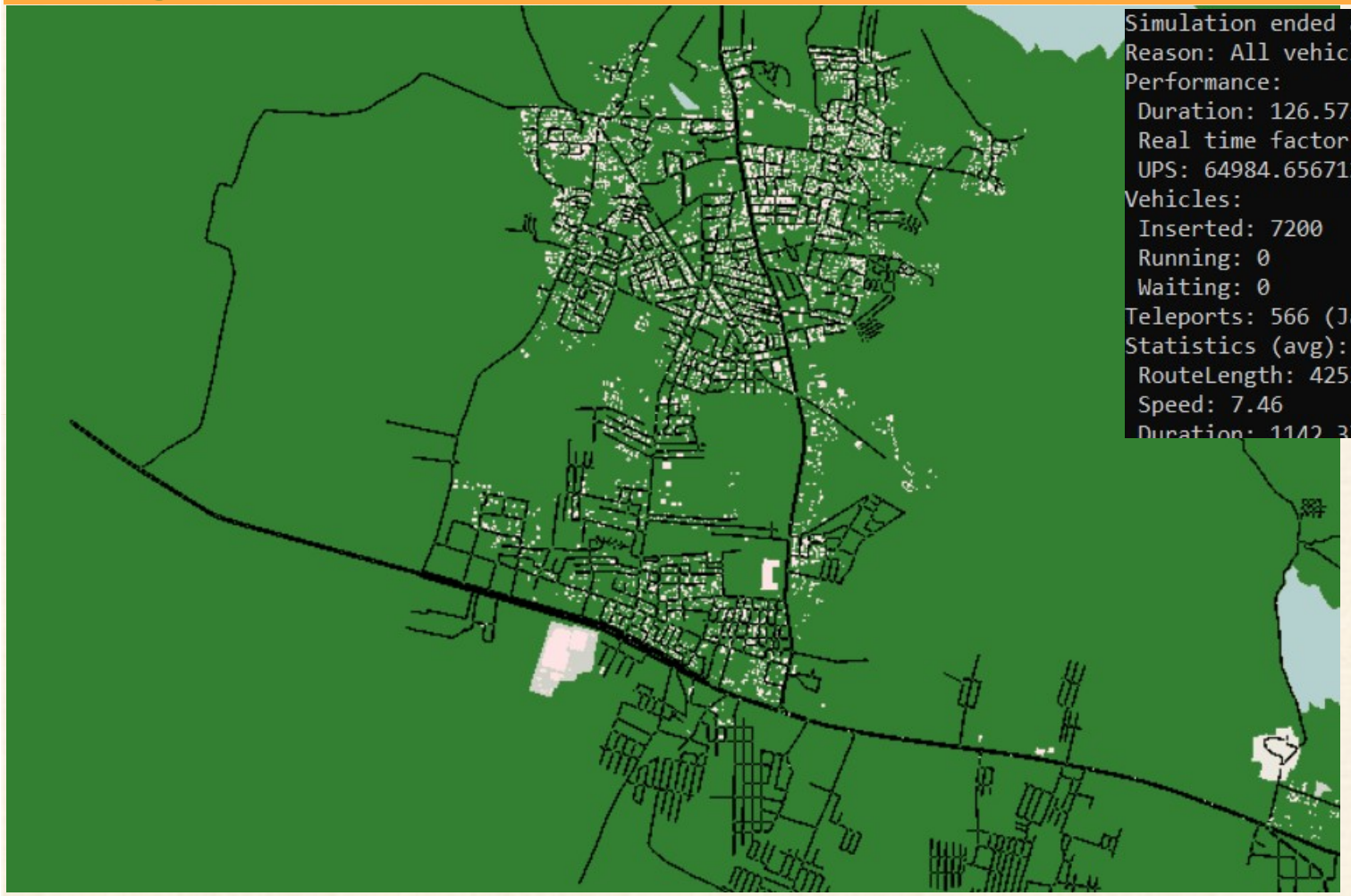

```
Simulation ended at time: 7064.00
Reason: All vehicles have left the simulation
Performance:
 Duration: 126.57s
 Real time factor: 55.811
 UPS: 64984.656712
Vehicles:
 Inserted: 7200
 Running: 0
 Waiting: 0
Teleports: 566 (Jam: 163, Yield: 226, Wrong L
Statistics (avg):
 RouteLength: 4253.19
 Speed: 7.46
 Duration: 1142.37
```

Simple query

What is the average waiting time or delay?

Background and Motivation

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Complex query

What is the probability that emergency vehicle reached near hospital within 10 min under given traffic condition?

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What is the probability that emergency vehicle reached near hospital within 10 min under given traffic condition?

What is the traffic volume at Intersection-1 which causes the deadlock at Intersection-2?

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(Statistical) Model Checking [1]

combines simulation and statistical methods for the analysis of stochastic systems

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1 - Legay A., Delahaye B., Bensalem S. (2010) Statistical Model Checking: An Overview. In: Barringer H. et al. (eds) Runtime Verification. RV 2010. Lecture Notes in Computer Science, vol 6418. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-16612-9_11

Background and Motivation

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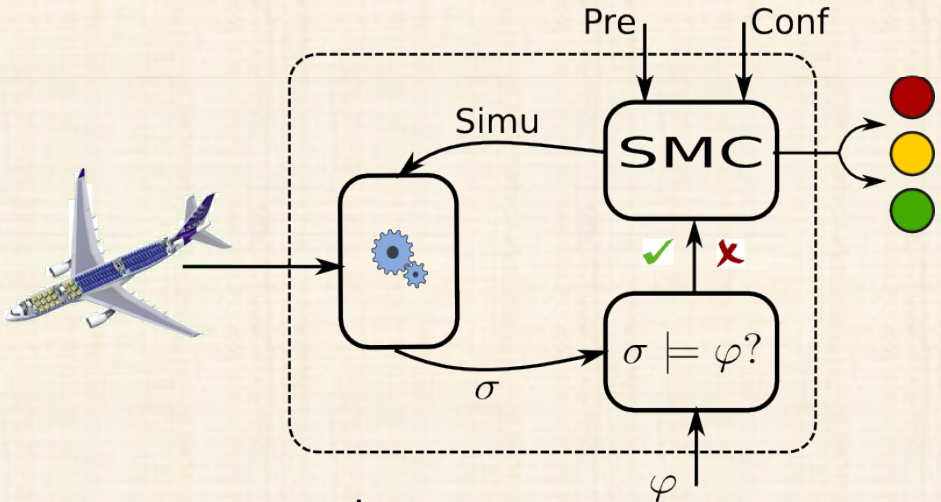

Source: https://project.inria.fr/plasma-lab/statistical-model-checking/

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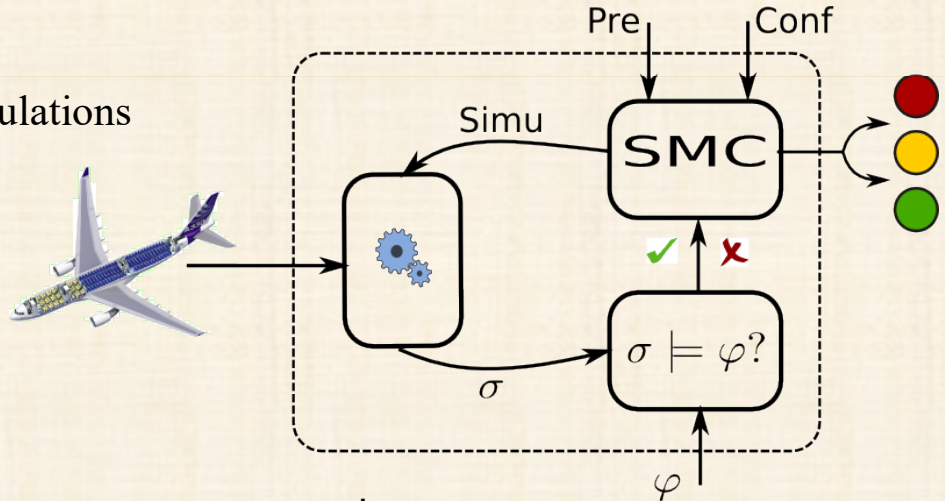
Background and Motivation

(Statistical) Model Checking [1]

combines simulation and statistical methods for the analysis of stochastic systems

- Model + (temporal) logic (e.g PCTL)
- Monte-carlo sampling of the runs of the system
- Chernoff hoeffding for confidence interval calculations



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Car-following models

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A method used to determine how vehicles follow one another on a roadway

- higher the speed of the vehicle, higher will be the spacing between the vehicles
- safe distance

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- Krauss [1]
- Wiedemann [2]
- Intelligent Driver Model [3]

1: Krauß, S., Wagner, P., Gawron, C.: Metastable states in a microscopic model of traffic flow. Physical Review E 55(5), 5597 (1997)

2: Wiedemann, R.: Simulation des strassenverkehrsflusses. Institut fur Verkehrswesen der Universitat Karlsruhe (1994)

3: Treiber, M., Hennecke, A., Helbing, D.: Congested traffic states in empirical observations and microscopic simulations. Physical review E 62(2), 1805 (2000)

Background and Motivation

Lane-changing models

The subject vehicle in the current lane tries to change direction either to its left or to its right

- If the gap in the selected lane is acceptable the lane change occurs or else it will remain in the current lane

- LC2013 [1]
- SL2015 [2]

1: Mintsis, E., Koutras, D., Porfyri, K., Mitsakis, E., L¨ucken, L., Erdmann, J., Fl¨otter¨od, Y.P., Alms, R., Rondinone, M., Maerivoet, S., Carlier, K., Zhang, X., Blokpoel, R., Harmenzon, M., Boerma, S.: Transaid deliverable 3.1 – modelling, simulation and assessment of vehicle automations and automated vehicles' driver behaviour in mixed traffic (09 2019)

2: Erdmann, J.: Sumo's lane-changing model. In: Modeling Mobility with Open Data, pp. 105–123. Springer (2015)

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MultiVeStA [1]

1 - Sebastio, Stefano, and Andrea Vandin. "MultiVeStA: Statistical model checking for discrete event simulators." (2013): 1-10.

Tools

MultiVeStA [1]

SUMO - *Simulation of Urban Mobility [2]*

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2 - Krajzewicz, Daniel, Jakob Erdmann, Michael Behrisch, and Laura Bieker. "Recent development and applications of SUMO-Simulation of Urban MObility." International journal on advances in systems and measurements 5, no. 3&4 (2012).

Tools

MultiVeStA [1]

Statistical Model Checking tool - from VeStA [3] family

Support direct integration with discrete time simulator

QUAntitative Temporal EXpressions language (QuaTEx) - **express systems properties ,supports PCTL,CSL.**

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3: Sen, Koushik & Viswanathan, Mahesh & Agha, Gul. (2005). VESTA: A statistical model-checker and analyzer for probabilistic systems. QEST 2005 - Proceedings Second International Conference on the Quantitative Evaluation of SysTems. 2005. 251 - 252. 10.1109/QEST.2005.42.

Tools

MultiVeStA [1]

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Support direct integration with discrete time simulator

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SUMO - *Simulation of Urban Mobility [2]*

Microscopic traffic simulator

Support online interaction through **Traci**

Support several car-following and lane-changing models

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3: Sen, Koushik & Viswanathan, Mahesh & Agha, Gul. (2005). VESTA: A statistical model-checker and analyzer for probabilistic systems. QEST 2005 - Proceedings Second International Conference on the Quantitative Evaluation of SysTems. 2005. 251 - 252. 10.1109/QEST.2005.42.

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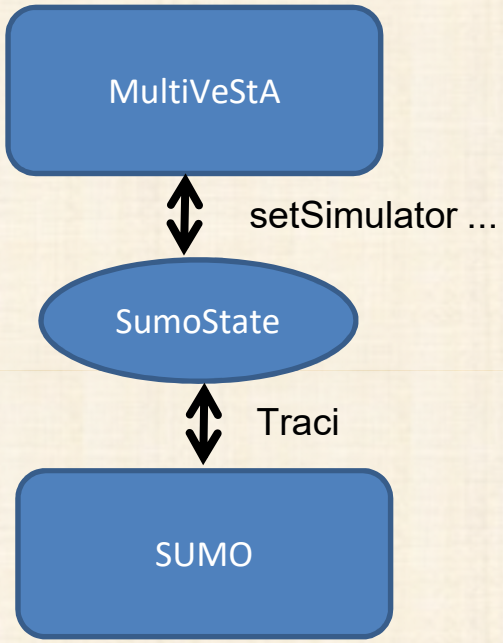
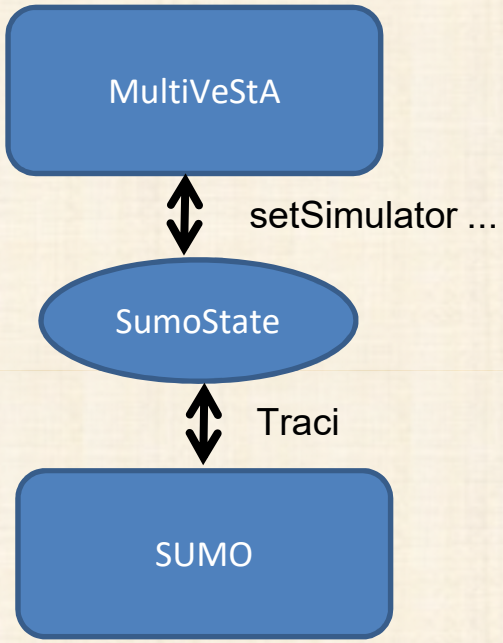


Integration of MultiVeStA and SUMO

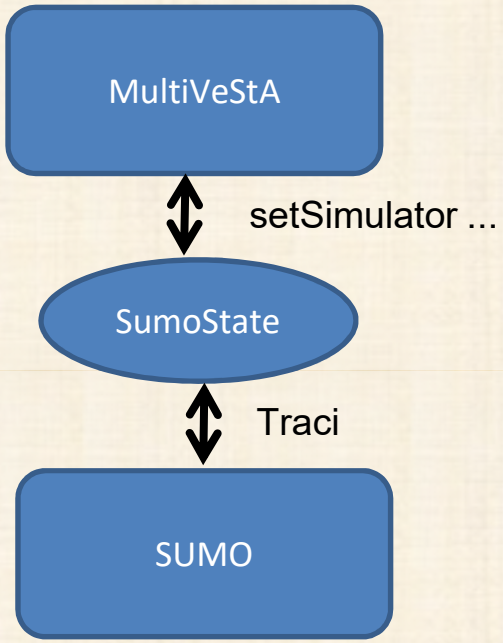
MultiVeStA + SUMO



Integration of MultiVeStA and SUMO

MultiVeStA + SUMO

setSimulatorForNewSimulation(randomSeed)

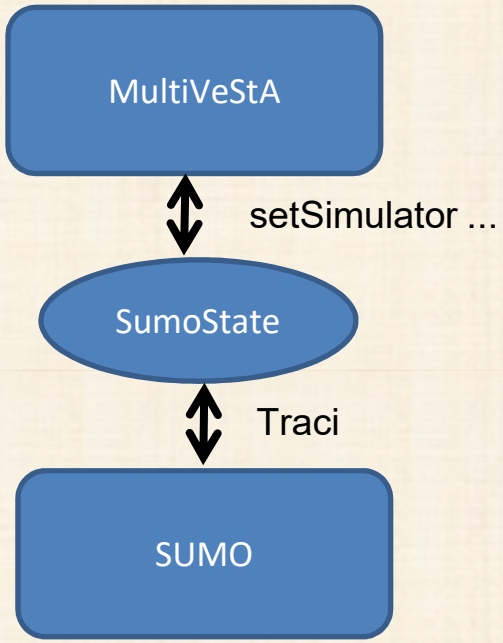


Integration of MultiVeStA and SUMO

MultiVeStA + SUMO

setSimulatorForNewSimulation(randomSeed)

performOneStepOfSimulation()



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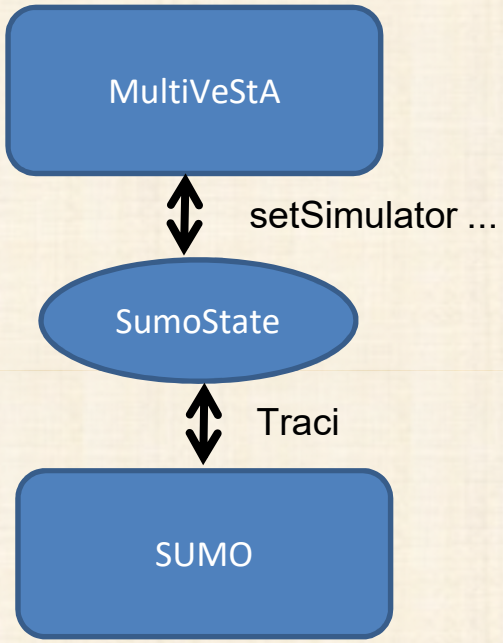
MultiVeStA + SUMO

setSimulatorForNewSimulation(randomSeed)

performOneStepOfSimulation()

rval(int)



Integration of MultiVeStA and SUMO

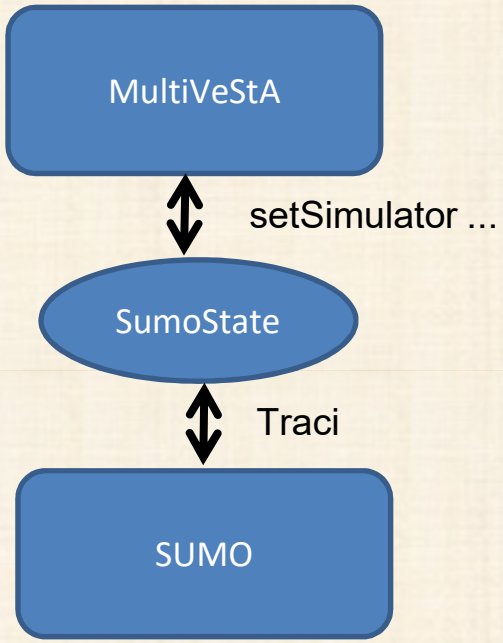
MultiVeStA + SUMO

setSimulatorForNewSimulation(randomSeed)

performOneStepOfSimulation()

rval(int)

rval(0) - the current time
rval(3) - the number of cars waiting
rval(4) - the time loss of vehicle
rval(6) - number of vehicles that reach their destination
rval(7) - the CO2 emission



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Road network with hospital and emergency vehicle

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Road network with hospital and emergency vehicle

```
-m data / cross . sumocfg
-l serversLists / oneLocalServer
-f quatex / exper1 . quatex
- bs 30 -a 0.1 - d1 x
// x = 2 for queries for non probabilistic operator
// x = 0.1 for these queries probabilistic operator
- vp TRUE
- osws ONESTEP - sots 0 - sd sumoState
```

Parameters of MultiVeStA Client

Some Results

Simple Query:

Estimate expected CO2 emissions
within simulation time.

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Estimate expected CO2 emissions
within simulation time.

```
expCo2Emission(x) = if ( s. rval (0) >= x )
then (s.rval(7))
else # expCo2Emission ((x)) fi ;

eval parametric(E[ expCo2Emission ((k)) ],
k,1.0,1.0 ,100.0) ;
```

Some Results

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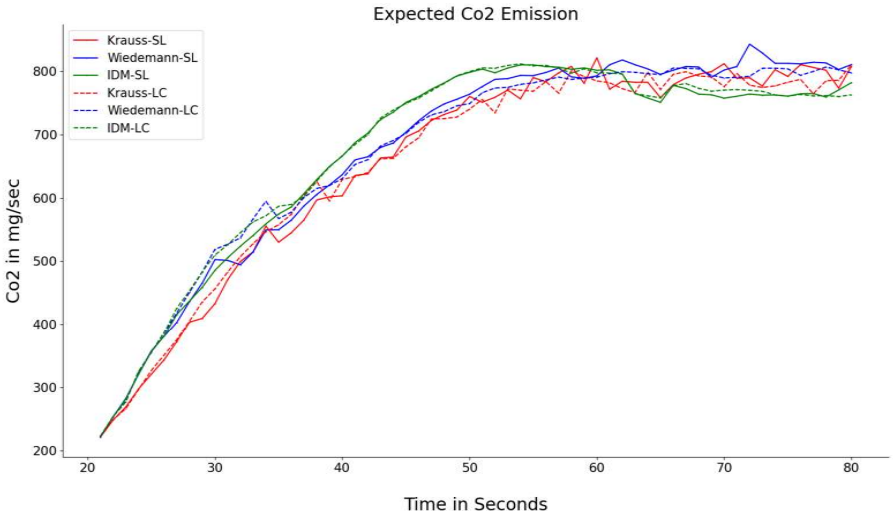
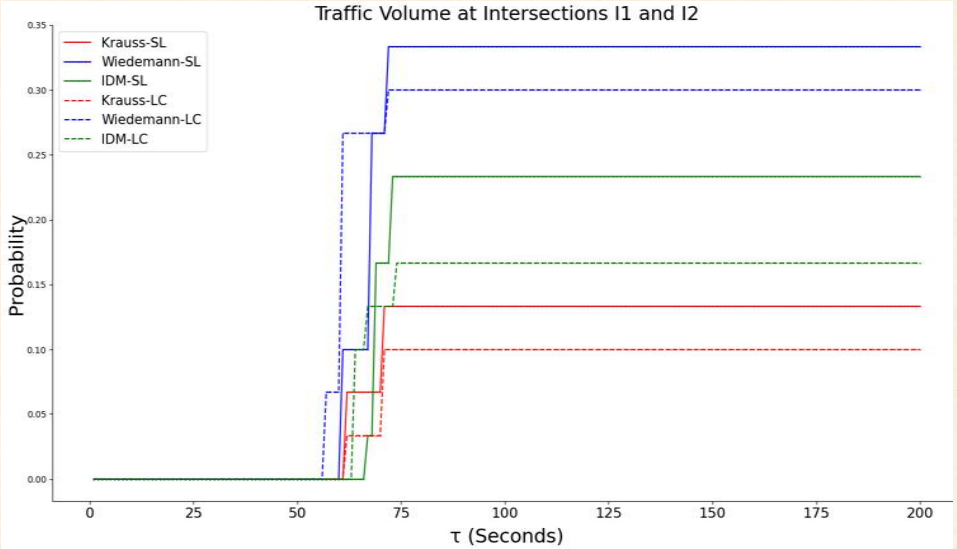


Expected CO_2 for various models

Some Results

Complex Query:

The traffic volume at intersection I1 is less **until** the point the traffic volume is high at the intersection I2

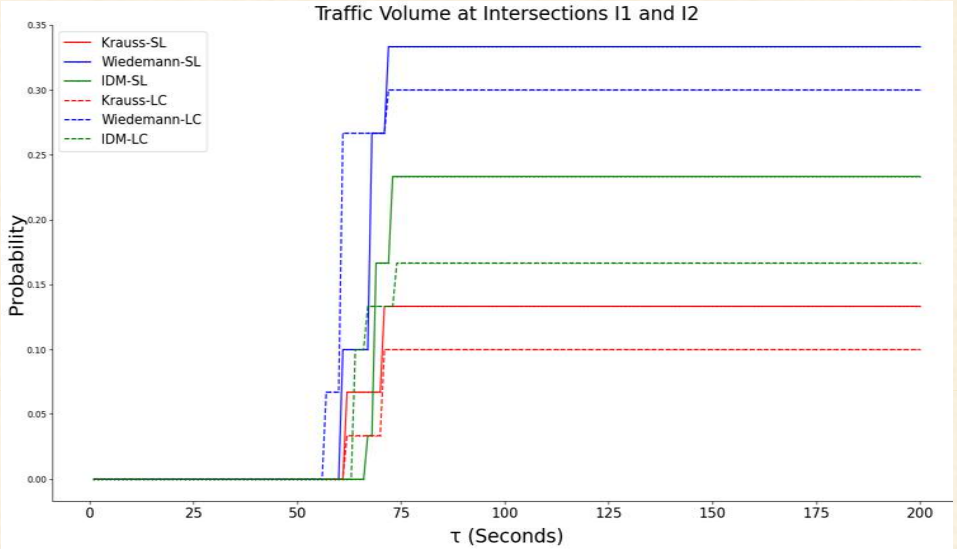


Some Results

Complex Query:

The traffic volume at intersection I1 is less **until** the point the traffic volume is high at the intersection I2

```
t1Ut2(k,x,y) = if( s.rval (0) <= k)
                    then if ( s.rval(11) > x )
                            then (1)
                         else if ( s.rval (10) <= y )
                            then #t1Ut2((k),(x),(y))
                         else (0) fi fi
                 else (0) fi ;
eval parametric(E[ t1Ut2((k) ,(20),(15)) ],
k, 1.0, 1.0, 200.0);
```



Probability that the "traffic volume" at I1 is less than 15 Until the traffic volume at I2 is greater than 20.

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Use of this tool chain for studying microscopic traffic models other than lane-changing and car-following models.

More penetrating and insightful queries on large systems for impactful analyses.

https://github.com/ThamilselvamB/Multivesta-With-SUMO

Acknowledgement

Acknowledgement

M2Smart: Smart Cities for Emerging Countries based on Sensing, Network and Big Data Analysis of Multimodal Regional Transport System, JST/JICA SATREPS(Program ID JPMJSA1606),Japan

DST National Mission for Interdisciplinary Cyber-Physical Systems (NM-ICPS), Technology Innovation Hub on Autonomous Navigation and Data Acquisition Systems: **TiHAN** Foundations at Indian Institute of Technology (IIT) Hyderabad.

Thanks

Questions?